
DGPS BROADCAST SITE SIGNAL COVERAGE

A nationwide DGPS service will require DGPS broadcast sites distributed across the country to provide the DGPS correction signal to all surface users. In order to determine the optimum location of these DGPS broadcast sites, a medium frequency radio propagation model was utilized along with the operating parameters of each DGPS broadcast site, to predict the signal coverage of the individual broadcast sites. The signal coverages of the individual sites were then combined to determine the predicted signal coverage that would be obtained with a nationwide network of DGPS broadcast sites. The radio propagation model that was used was validated by conducting signal strength measurements at several operating U.S. Coast Guard (USCG) DGPS broadcast sites.^[10] The signal coverage predicted for these radiobeacon transmitters is aided by the use of the medium frequency 285 to 325 kHz band, which provides the advantages of a large coverage range with low power transmitters and a minimum effect of terrain features on the propagation of radio waves. During normal operation the minimum field strength of the DGPS broadcast signal will be 75 microvolts per meter (uV/m) in the specified coverage area. Although the effects of terrain on the signal strength is minor in this frequency band, shadowing by terrain may reduce the signal level in some very rugged areas.

In order to provide the most cost effective solution to the implementation of a nationwide DGPS service, maximum use was made of existing DGPS broadcast sites and other infrastructure. The signal coverage obtained is presented below in four stages:

1. Existing USCG and U.S. Army Corps of Engineers (COE) DGPS signal coverage
2. Existing Ground Wave Emergency Network (GWEN) radio broadcast site signal coverage
3. Additional sites required for nationwide signal coverage
4. Additional sites required for redundant signal coverage

5.1 USCG and COE DGPS Signal Coverage

The basis of the nationwide DGPS service is the network of DGPS broadcast sites now in operation or proposed by the USCG and COE, providing DGPS correction signal coverage to coastal areas, harbors, and inland waterways. The network was originally designed to provide signal coverage for harbor and harbor approach areas, and other critical waterways for which the USCG provides aids to navigation. The service has been extended to provide coverage for the Great Lakes and the Mississippi River, resulting in a network of DGPS broadcast sites that provide radiobeacon signal coverage to over two thirds of the continental United States, as shown in

Figure 5.1. The locations and operating parameters of the DGPS broadcast sites making up this network is described in Table 5.1.

5.2 Existing GWEN Radio Transmitter Site Signal Coverage

Table 5.1 USCG and COE DGPS broadcast site information.

Broadcast Site	Frequency	Power	Latitude	Longitude
	kHz	W (ERP)	(N)	(W)
Sandy Hook, NJ	286	5	40 28 17	074 00 42
Key West, FL	286	4	24 00 00	082 00 00
Fort Stevens, OR	287	27	46 12 18	123 57 21
Pigeon Point, CA	287	27	37 10 55	122 23 35
Portsmouth Harbor, ME	288	3	43 04 15	070 42 37
Cape Henry, VA	289	7	36 55 38	076 00 24
Cape Canaveral, FL	289	35	28 27 35	080 32 35
Louisville, KY	290	170	38 15 00	085 45 00
Cheboygan, MI	292	15	45 39 10	084 28 00
Cape Mendocino, CA	292	27	40 26 29	124 23 56
English Turn, LA	293	42	29 52 44	089 56 31
Montauk Point, NY	293	7	41 04 02	071 51 38
Fort Macon, NC	294	7	34 41 52	076 40 59
Virginia Key, FL	295	2	25 15 00	080 30 00
Galveston, TX	296	22	29 19 45	094 44 10
Wisconsin Point, WI	296	1	46 42 16	092 01 01
Huntington, WV	296	170	38 50 00	082 30 00
Milwaukee, WI	297	10	43 00 06	087 53 18
Cape Henlopen, DE	298	22	38 46 36	075 05 16
Charleston, SC	298	11	32 45 28	079 59 35
Upper Keweenaw, WI	298	20	47 13 21	088 37 18
Omaha, NE	298	13	41 46 42	095 54 39
Sallisaw, OK	299	170	35 30 00	095 00 00
Mobile Point, AL	300	17	30 13 38	088 01 24
Saginaw Bay, MI	301	4	43 37 43	083 50 17
Whidbey Island, WA	302	4	48 18 46	122 41 46
Point Loma, CA	302	27	32 39 54	117 14 33
Aransas Pass, TX	304	22	27 50 18	097 03 33
Kansas City, KS	305	170	39 10 00	094 45 00
Knoxville, TN (TVA)	306	170	45 41 18	119 08 35
Neebish Island, MI	309	3	46 19 17	084 09 02
Reedy Point, NJ	309	3	39 33 41	075 34 11

Table 5.1 (continued) USCG and COE DGPS broadcast site information.

Broadcast Site	Frequency	Power	Latitude	Longitude
	kHz	W (ERP)	(N)	(W)
Memphis, TN	310	35	35 27 56	090 12 21
Point Blunt, CA	310	2	37 51 12	122 25 04
Rock Island, IA	311	120	42 00 30	090 14 00
Egmont Key, FL	312	42	27 36 16	082 45 40
Pittsburgh, PA	312	170	40 15 00	080 00 00
Vicksburg, MS	313	60	32 19 53	090 55 11
Andrews Locks, FL	314	170	31 00 00	085 00 00
Brunswick, ME	316	7	43 53 42	069 56 17
St. Paul, MN	317	120	44 18 15	091 54 14
Whitefish Point, MI	318	3	46 46 17	084 57 29
Detroit, MI	319	7	42 17 49	083 05 41
Millers Ferry, AL	320	170	32 05 24	087 23 44
Point Arguello, CA	321	27	34 34 39	120 38 38
Miami, FL	322	25	25 43 56	080 09 38
Sturgeon Bay, WI	322	10	44 47 40	087 18 49
Youngstown, NY	322	30	43 14 10	079 01 03
St. Louis, MO	322	120	38 36 41	089 45 31
Robinson Point, WA	323	3	47 23 15	122 22 29
Gunthersville, AL	323	170	34 30 00	086 20 00
Chatham, MA	325	5	41 40 17	069 57 02
Chattanooga, TN	325	170	35 05 00	085 40 00

The existing radio transmitter sites, recommended here for incorporation into the nationwide DGPS service, are part of the Ground Wave Emergency Network (GWEN), owned by the Air Force Air Combat Command. The GWEN sites are existing Federal government assets, and these radio broadcast sites are scheduled for decommissioning in the same time frame that the nationwide DGPS service would be installed. The Air Force currently has 57 GWEN transmitter sites, covering the continental U.S. Fifteen of the GWEN sites are at locations that would be useful in completing the nationwide, single coverage of the DGPS correction signal. The GWEN sites currently transmit at 150 to 175 kHz and could be easily modified to accept the 285 to 325 kHz radiobeacon signal. The equipment required at the DGPS broadcast sites would be installed in the existing enclosures, the existing broadcast antenna would be used, and the cost and delay of land acquisition and environmental impact statements would be avoided.

The GWEN transmitter sites include the following features, all applicable to the DGPS broadcast site.

- (a) A 299-foot broadcast antenna tower

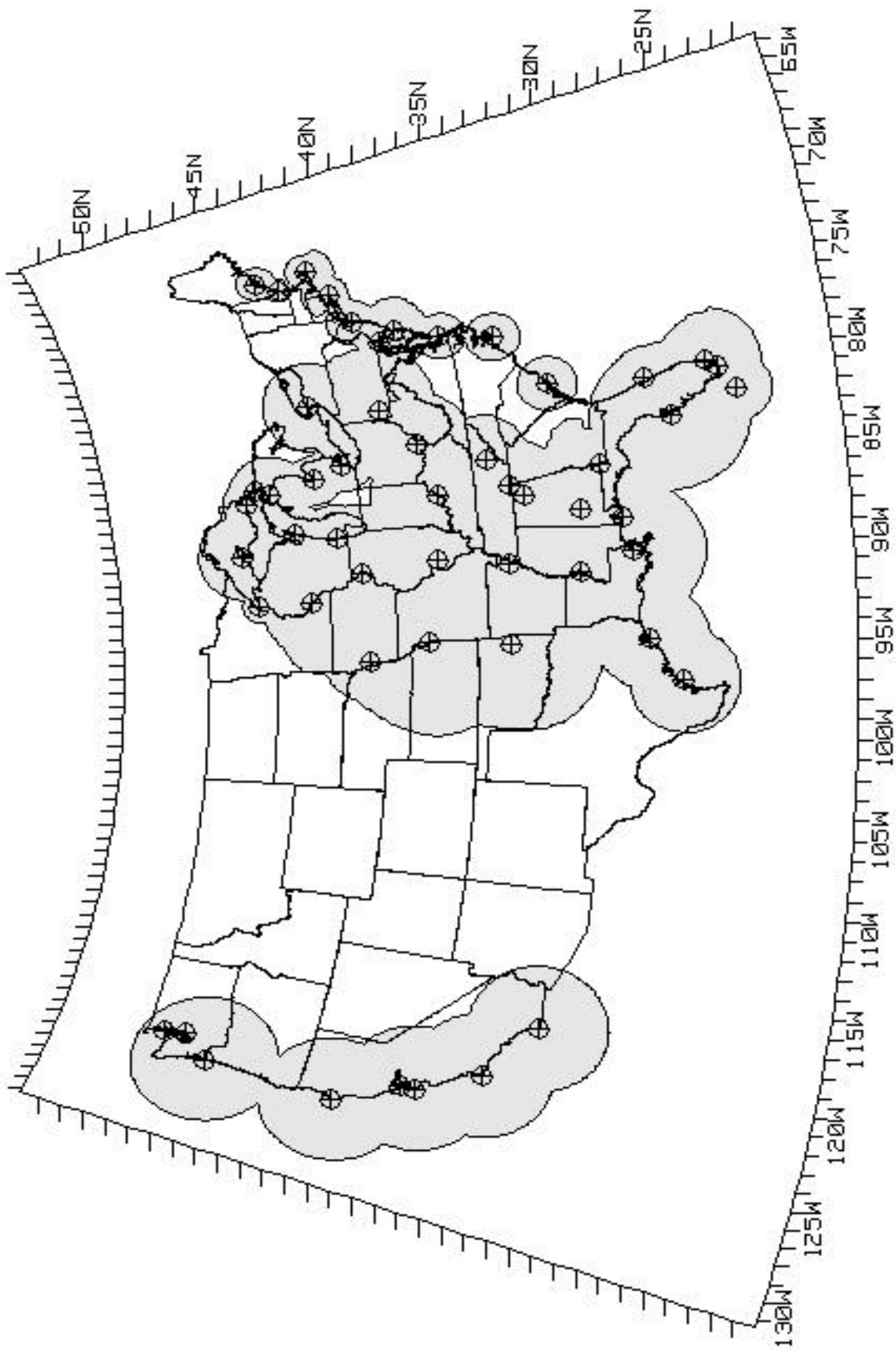


Figure 5.1. Predicted signal coverage for existing USCG and COE DGPS broadcast sites.

- (b) A large ground plane, designed for ground conductivity conditions at the site
- (c) An antenna tuning unit enclosure at the base of the tower
- (d) Two equipment shelters
- (e) Electronic racks that will accept the DGPS equipment
- (f) All utilities that are required for operation of the DGPS broadcast site
- (g) Air conditioning and environmental controls
- (h) Back-up power generators
- (i) Above ground fuel storage tanks
- (j) Security enclosures with intrusion alarms

The DGPS correction signal coverage provided by adding these 15 existing GWEN radio transmitter sites to the existing USCG and COE DGPS broadcast sites is shown in Figure 5.2. The locations and operating parameters of these broadcast sites is described in Table 5.2. In order to obtain the signal coverage shown in these figures for added broadcast sites, it will be necessary to design the transmitter at each broadcast site to provide the signal field strength indicated in the tables, at a distance of 10 kilometers from the site.

5.3 Additional Sites Required for Nationwide Signal Coverage

As shown in Figure 5.2, with 15 existing GWEN radio broadcast sites added to the USCG and COE DGPS broadcast sites, there are still a few areas that are not covered by the DGPS correction signal. This requires the addition of seven additional USCG type DGPS broadcast sites, and increasing the transmitter power at six USCG broadcast sites, to complete the nationwide coverage. The DGPS correction signal coverage with these 7 additional sites is shown in Figure 5.3. The locations and operating parameters of these additional sites are described in Table 5.3. It should be noted that the recommended DGPS broadcast site locations that have been added to complete the nationwide coverage were selected as optimum locations, and at these frequencies location of the site up to 10 miles from the optimum location will have very little effect on the nationwide coverage plan.

5.4 Additional Sites Required for Redundant Signal Coverage

The nationwide DGPS signal coverage shown in Figure 5.3 was derived to insure that all locations, nationwide, would have access to the DGPS correction signal. Increasing the coverage so that most locations nationwide will be covered by at least two DGPS broadcast sites, providing additional signal availability, requires the addition of sixteen more DGPS broadcast sites, and increasing the transmitter power at nine USCG broadcast sites. The redundant DGPS correction signal coverage with these 16 additional sites is shown in Figure 5.4. The locations and operating parameters of these additional sites is described in Table 5.4.

5.5 Frequency Assignments

Existing USCG and COE DGPS broadcast sites have an operating frequency assigned in the 285 to 325 kHz band. These assignments are noted in Table 5.1. The operating frequencies recommended for new DGPS broadcast sites have been selected to avoid interference with other DGPS broadcast

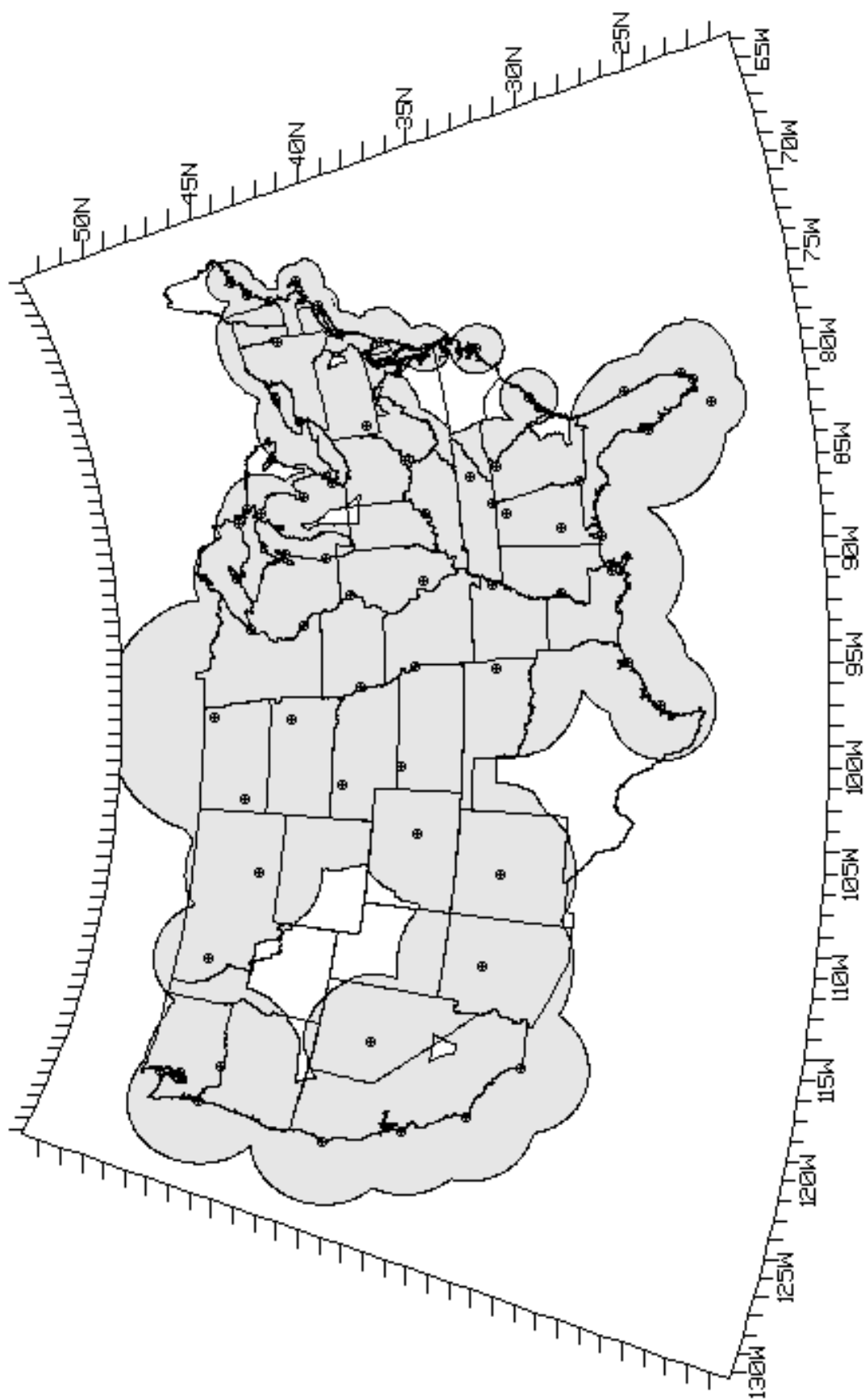


Figure 5.2. Predicted signal coverage for 15 existing GWEN radio transmitter sites added to the USCG and COE DGPS broadcast sites.

Table 5.2 Existing GWEN radio transmitter site information.

Broadcast Site	Frequency	Power	Field Strength	Latitude	Longitude
	kHz	W (ERP)	dbuV/m @ 10 km	(N)	(W)
Goodland, KS	286	300	82.6	39 49 39	100 39 49
Ronan, MT	287	170	80.1	47 34 47	114 06 50
Penobscot, ME	290	13	68.9	44 26 07	068 47 22
Kirtland, NM	291	300	82.6	34 57 26	106 29 32
Appleton, WA	300	300	82.6	45 46 55	121 19 34
Macon, GA	301	300	82.6	34 41 39	083 33 38
Medora, ND	306	100	77.8	46 54 22	103 16 29
Edinburg, ND	307	300	82.6	48 33 31	097 47 04
Clark, SD	309	300	82.6	44 56 03	097 57 38
Whitney, NE	310	300	82.6	42 30 00	102 00 00
Austin, NV	312	300	82.6	39 30 00	117 30 00
Billings, MT	313	300	82.6	45 58 19	107 59 47
Flagstaff, AZ	319	300	82.6	35 13 18	111 49 06
Hudson Falls, NY	324	300	82.6	43 16 13	073 32 19
Pueblo, CO	325	300	82.6	38 51 54	104 34 31

Table 5.3 Additional DGPS broadcast site information.

Broadcast Site	Frequency	Power	Field Strength	Latitude	Longitude
	kHz	W (ERP)	dbuV/m @ 10 km	(N)	(W)
Odessa, TX	285	170	80	31 50 00	102 20 00
Arlington, TX	294	170	80	32 40 00	097 00 00
Jackson, WY	301	170	80	44 00 00	110 06 00
Greensboro, NC	301	170	80	36 00 00	079 30 00
Duchesne, UT	303	170	80	40 36 00	110 24 00
El Paso, TX	316	170	80	32 00 00	106 20 00
Sun Valley, ID	320	170	80	43 00 00	115 00 00

sites, and with Federal Aviation Administration beacons, civil radiobeacons licensed by the Federal Communications Commission, Canadian DGPS beacons, Canadian aviation beacons, and Mexican aviation beacons that operate in this frequency band. The recommended frequencies are noted in Tables 5.1 through 5.4. Since frequency assignments in this band are dynamic, the situation will need to be reevaluated when application for a frequency assignment is made at a specific location.

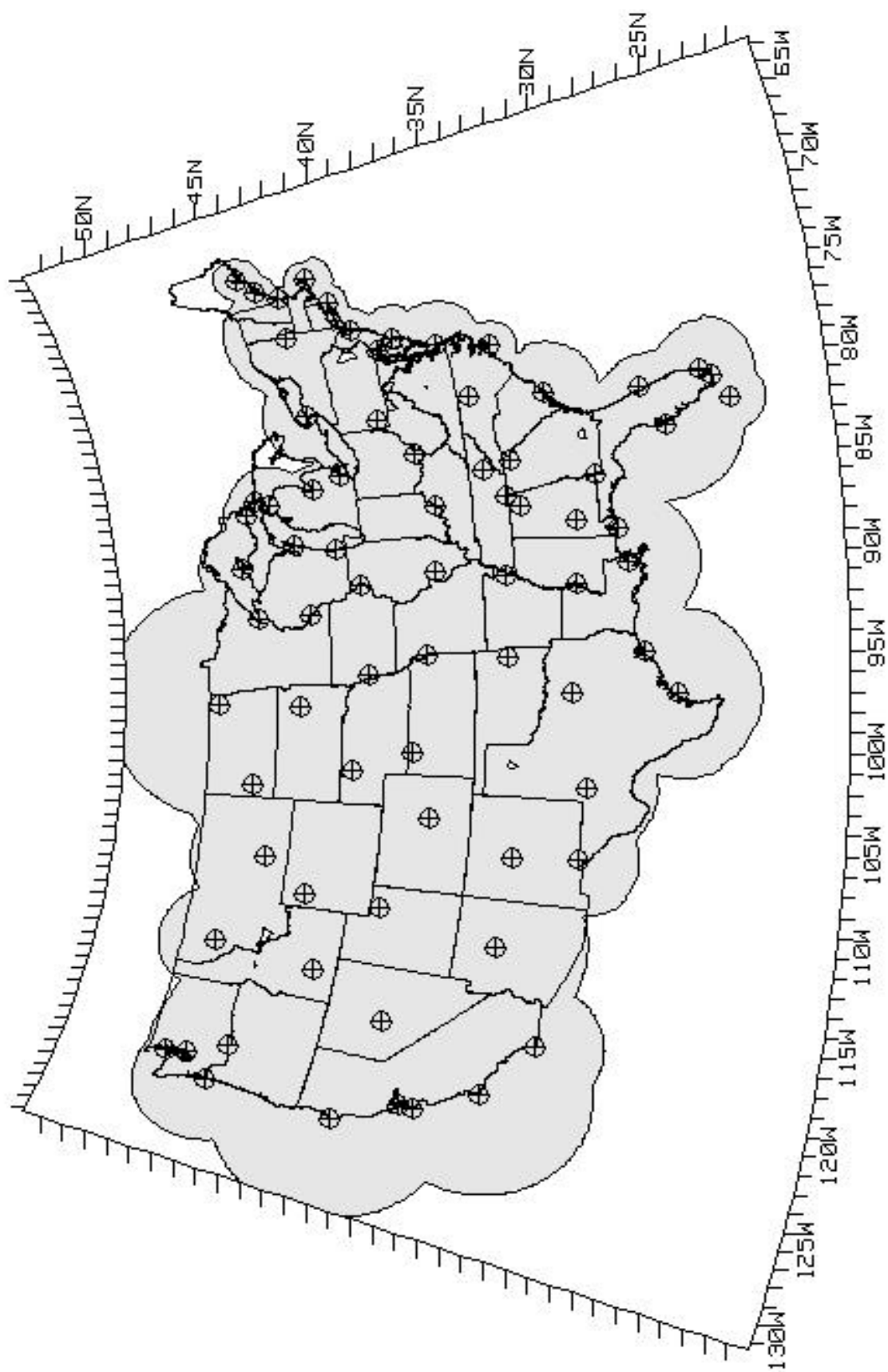


Figure 5.3. Predicted signal coverage with 7 additional DGPS broadcast sites.

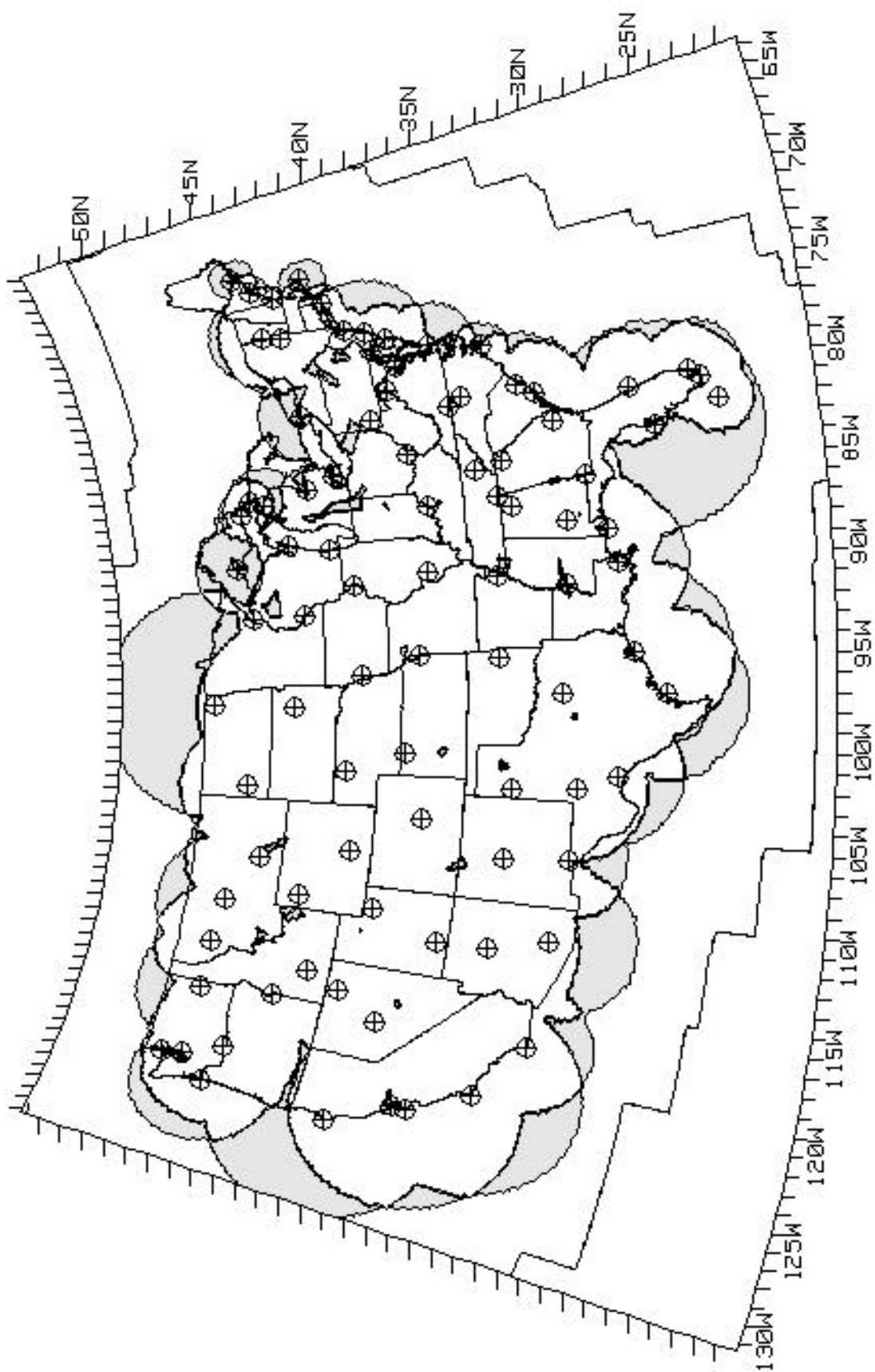


Figure 5.4. Nationwide redundant signal coverage.

Table 5.4 Additional redundant coverage DGPS broadcast site information.

Broadcast Site	Frequency	Power	Field Strength	Latitude	Longitude
	kHz	W (ERP)	dbuV/m @ 10 km	(N)	(W)
GWEN Sites					
Savanna, GA	285	300	82.6	32 08 22	081 41 49
Kensington, SC	292	300	82.6	33 28 51	079 20 35
Egg Harbor, NJ	311	300	82.6	39 36 12	074 22 16
Great Falls, MT	314	300	82.6	47 18 13	111 10 19
Goldwein, VA	315	300	82.6	38 37 09	076 52 51
Spokane, WA	316	300	82.6	47 31 10	117 25 21
Summerfield, TX	318	300	82.6	34 49 28	102 30 43
Other Sites					
Tucson, AZ	286	170	80	32 30 00	111 00 00
West, TX	289	170	80	30 00 00	101 30 00
Weiser, ID	291	170	80	44 20 00	117 00 00
Rawlins, WY	297	170	80	42 00 00	107 00 00
South, UT	307	170	80	37 30 00	112 00 00
Winchester, VA	307	170	80	39 15 00	078 15 00
Martinsville, VA	310	170	80	36 40 00	080 00 00
Middleburg, VT	314	170	80	44 00 00	073 15 00
North, NV	315	170	80	41 30 00	116 00 00

5.6 Individual DGPS Broadcast Site Signal Coverage

The figures 5.5 through 5.42 show the predicted signal coverage for individual DGPS broadcast sites that will be required to complete the signal coverage for a nationwide DGPS service.